

The Reionization Transition

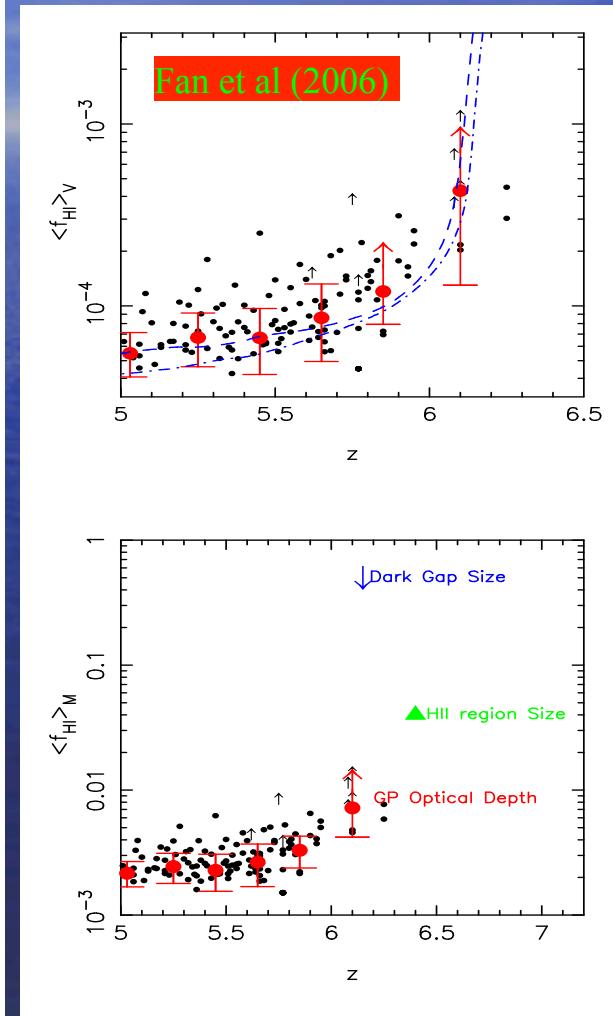
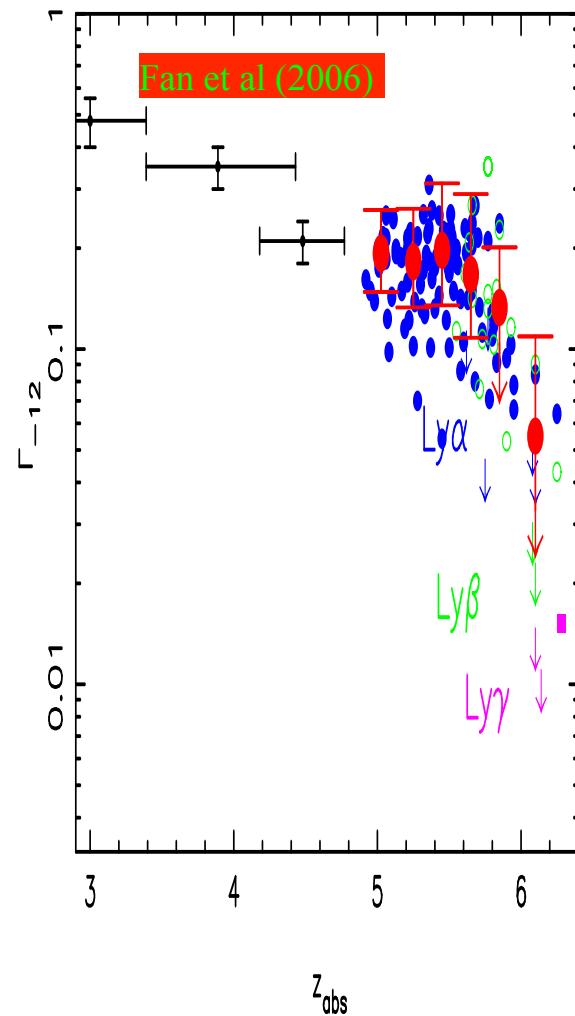
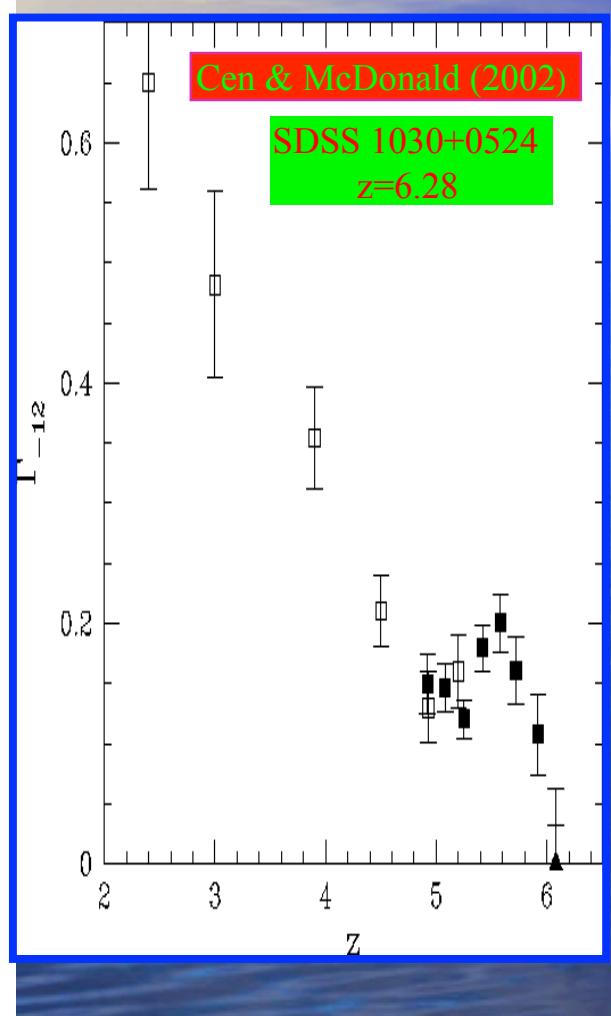
Renyue Cen

Princeton University Observatory

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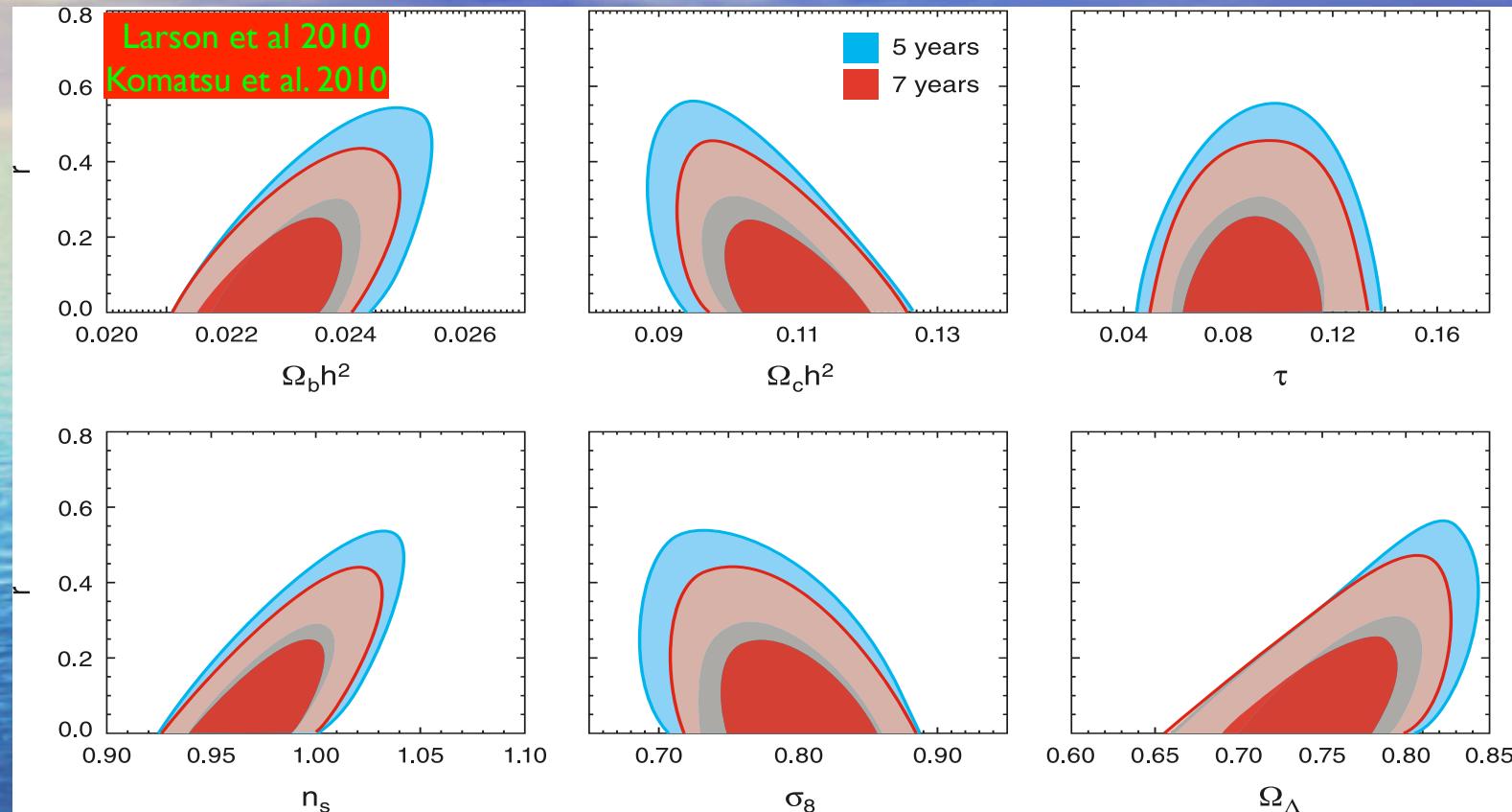
- What is reionization transition(s)?

Possible transition #1: neutral fraction changes from 10^{-4} to $>10^{-2}$ from $z=5.8$ to 6.3



Naïve implication: $\tau_e = 0.03-0.04$

Possible transition #2: WMAP7 $\tau_e = 0.088 \pm 0.015$



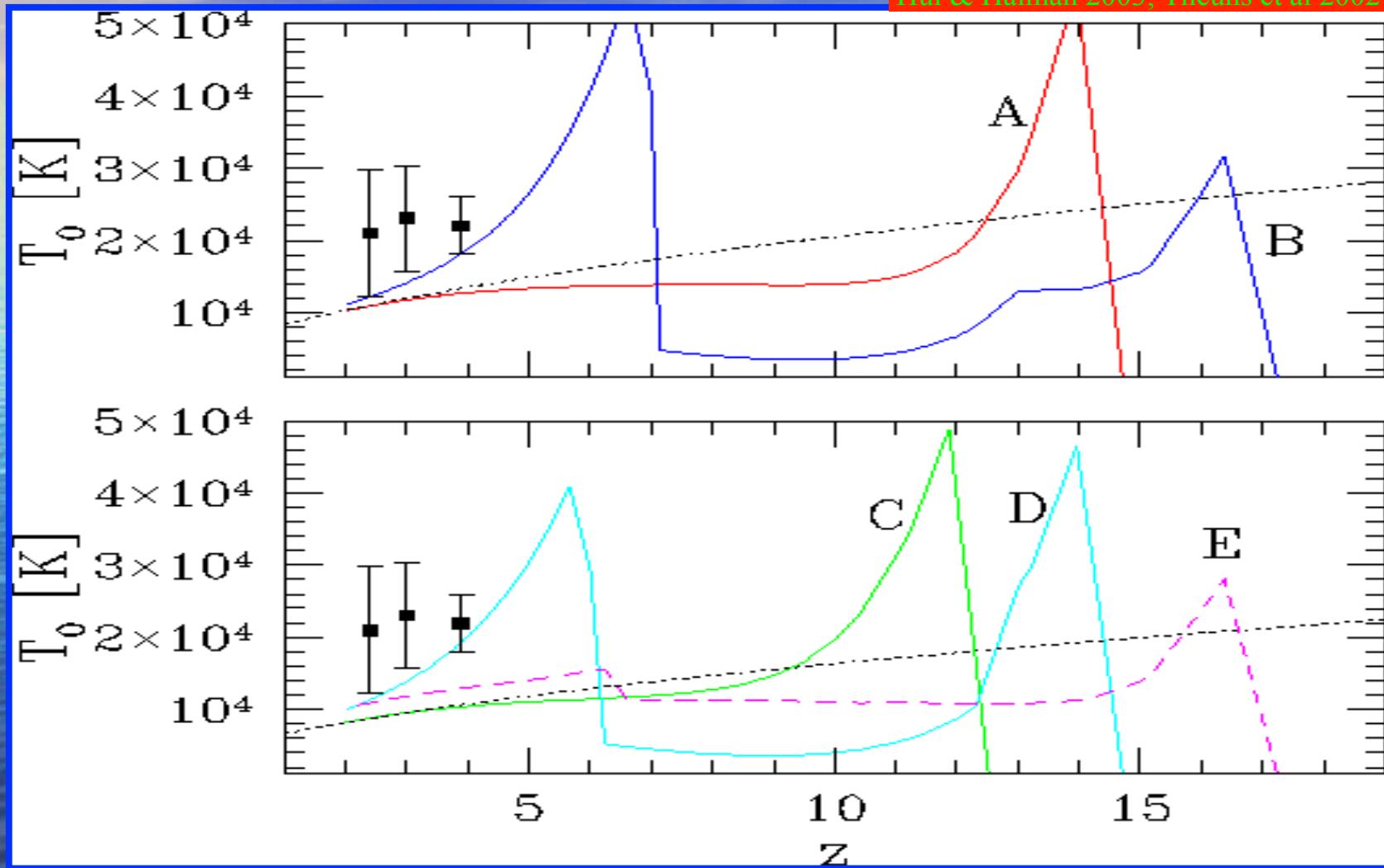
What does it mean?

$Z_{ri} \sim 8.1 - 12.9$ (2σ)
(assuming $x = n_{HI}/n_{H\text{tot}} = 0$)

Sudden reionization at $z = 6$ is ruled out at 3.8σ , suggesting that reionization was prolonged.

Possible transition #3: Ly α forest: $z_{\text{ri}} < 9-10$

Hui & Haiman 2003; Theuns et al 2002



Possible transition #4: Pop III → Pop II IMF

Population III, metal-free, massive stars → Pop II Salpeter IMF

Key physics 1: H₂ radiative cooling during initial collapse on galactic scales → the formation of gas cloud at end of free-fall phase with temperature of 200 K and density of 10⁴ cm⁻³ → ``loitering'' phase with density-independent cooling, slow, quasi-hydrostatic contraction → until Bonnor-Ebert mass of ~10³ Msun → gravitational collapse (Bromm et al 2002; Abel et al 2002)

Key physics 2: final zero-age main sequence massive star mass 60-300 Msun, limited primarily by photoevaporation-driven mass loss from proto-stellar accretion disk (McKee and Tan 2008)

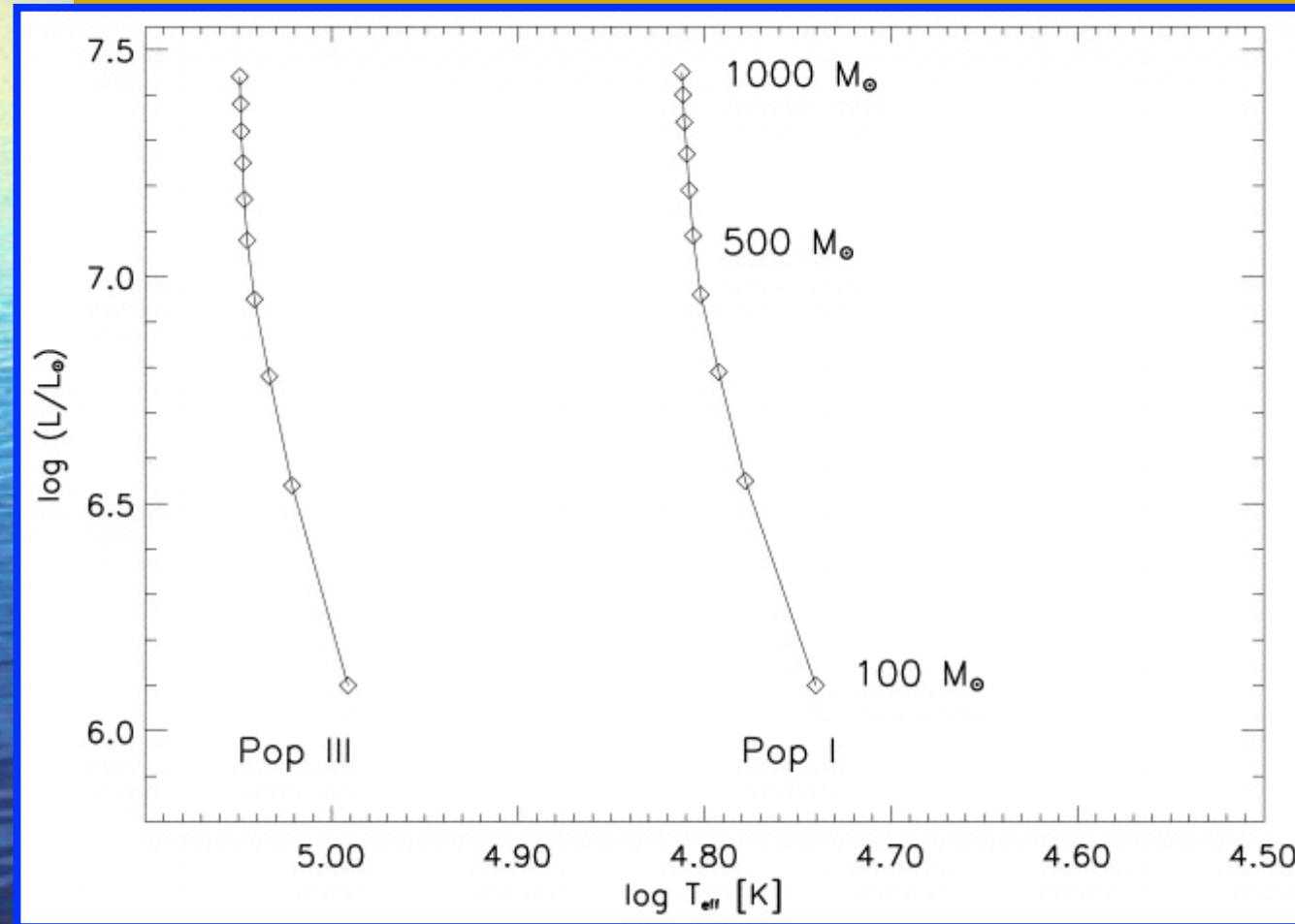
Key Physics 3: with C and O as primary elemental constituents of low-temperature coolants → Z_{crit}~10^{-3.5} (Bromm et al 2003)

Key Physics 4: with dust formation in Pop III PISN → Z_{crit}~10⁻⁶ (Schneider et al 2006; but see Cherchneff & Dwek 2010)

Possible transition #5: Ionizing photon efficiency

Pop III $M_* = 10-300 M_{\text{sun}}$: $e_{\text{UV}} = 40,000-100,000$ photons/baryon

Salpeter IMF $Z = 0.01 Z_{\text{sun}}$: $e_{\text{UV}} = 3500$ photons/baryon



$$\frac{e_{\text{UV}}(\text{Pop III})}{e_{\text{UV}}(\text{Pop II})} = 10-30$$

Bromm, Kudritzki & Loeb (2001)

Possible transition #6: double reionization

Cen (2003) – pre-WMAP model with $\tau_e = 0.10 \pm 0.02$

$$\eta = \text{prod. rate/destruction rate} \\ = c_* f_{\text{esc}} (df_h/dt) e_{\text{UV}} / C(I+z)^3$$

→ Double peaks: first @ $z_1 \sim 15$,
second @ $z_2 \sim 6$

- c_* : star formation efficiency
- f_{esc} : ionizing photon escape fraction
- e_{UV} : ionizing photon production efficiency
- df_h/dt : halo formation rate
- C : gas clumping factor

